Integration via Meaning: Using the Semantic Web to deliver Web Services

Brian M Matthews
CLRC, UK

Summary

The major developments of the World-Wide Web (WWW) in the last two years have been *Web Services* and the *Semantic Web*. The former allows the construction of distributed systems across the WWW by providing a lightweight middleware architecture. The latter provides an infrastructure for accessing resources on the WWW via their relationships with respect to conceptual descriptions. In this paper, I shall review the progress undertaken in each of these two areas. Further, I shall argue that in order for the aims of both the Semantic Web and the Web Services activities to be successful, then the Web Service architecture needs to be augmented by concepts and tools of the Semantic Web. This infrastructure will allow resource discovery, brokering and access to be enabled in a standardised, integrated and interoperable manner. Finally, I survey the CLRC Information Technology R&D programme to show how it is contributing to the development of this future infrastructure.

1 Introduction

The major initiatives in the development in the support of information system across the World-Wide Web (WWW) in the last two years have been *Web Services* and the *Semantic Web*, both of which have been taken up as major activities of the World-Wide Web Consortium (W3C), the leading standards body on the WWW.

Web Services have been one of the most talked about emerging technologies with major initiatives from the large manufacturers, such as IBM and Microsoft. With this major commercial backing it is seen as the next big step of the development and exploitation of the Intranet and Web infrastructure already in place so that businesses and other communities, such as science, government and education, can communicate and interact together in a flexible and automated manner.

The Semantic Web on the other hand has had a much longer development, and while it still has a degree of hype surrounding it, there has been much less commercial support. It seems to be met with as much mystification as excitement, as people do not understand what it seeks to achieve, and when they do understand, they cannot see how it can be used in practice.

However, the aims of these two initiatives are complementary, and in the long term very similar; to evolve the World-Wide Web into a seamless interactive, and automatic system of the future. In a sense, they both aim to make the Web both ubiquitous and invisible.

In this paper, we shall discuss the current state of the development of Web Services and the Semantic Web. We shall go on to discuss how they are complementary, and what areas can be supported through their combination, and then discuss the current programme of work at CLRC to move towards this combination.

2 Web Services

There is a definite buzz in the air at the moment about Web Services. This method of loosely integrating different application on the Web into a unified service is being proposed as a universal mechanism for seamlessly integrating services offered across the Web to provide integrated distributed systems. They have become the cornerstone of the enterprise integration platforms of major vendors such as Microsoft (.NET) and IBM (IBM Web Services). Indeed, it was the submission of the SOAP proposal to W3C by an industrial consortium in May 2000 which kick started the whole area.

Others who have been developing different approaches to developing open integrated distributed systems have been forced to change direction to accommodate the emerging consensus on Web Services. For example, Sun Microsystems has introduced classes supporting Web Services to its Java Enterprise Infrastructure (Sun Microsystems 2001). The ebXML initiative which was developing an alternative architecture for message passing via XML has changed course to use Web Services as a base technology underlying its customised approach (ebXML, Irani 2001). The Grid concept, an approach to developing large-scale distributed computing infrastructures to support high-performance computing, which has created particular interest within scientific applications (Foster & Kesselman 1999), has been seen as the natural successor to the Web. Nevertheless, the Grid community has recently recognised the usefulness of Web services as an underpinning of the further development of the Grid (Foster et. al. 2002); it is likely that in the future there will be a convergence Web and Grid technology around Web Services. A recent paper has also noted the complementary nature of Web Services and the well-established middleware architecture CORBA (Gokhale et. al. 2002). That Web Services is the method of choice for providing web-enabled integration of computing resources has become the consensus in the community is further supported by the UK government's *Electronic Government Interoperability Framework* recent recommendation of Web Services as the preferred integration method for the electronic delivery of public services (eGif 2002).

Nevertheless, despite this large amount of activity and publicity, there are few public examples of the use of Web Services in action, and there is remarkably little consensus of what Web Services are and what they offer! However, most definition seem to agree that Web Services require three basic components:

- **A Messaging Service**: a standard protocol for communicating between resources on the Web. The most common means of supporting this is currently SOAP (SOAP 1.2 Parts 1 & 2), although the W3C is now developing a standard recommendation for this purpose (XML Protocol).
- **An Interface Description Language:** a mechanism for services to describe their interfaces in a standard fashion, so client applications know what form (types) of messages to send to them, and what form the client should expect the response to be. The most common method for this to date is the Web Service Description Language (WSDL).
- **A Registration Service:** a mechanism of registering web services so that clients looking for a service to satisfy their requirements can find them easily. The Universal Discovery Description and Integration format (UDDI) is the most common mechanism proposed for this purpose.

In a sense, there is not very much new here. What these together provide is a *loosely coupled middleware solution.* It allows a relatively simple mechanism to publish and combine services together to provide integrated yet distributed systems, with out the need for expensive proprietary middleware components. It is based on open standards (TCP/IP, XML), and allows the integration of systems based on different platforms, which are independently provided and maintained. It is these advantages that make it more attractive than existing middleware solutions such as CORBA or DCE. Nevertheless, the basic infrastructure is relatively weak, and there are many proposals as to what to add to the basic infrastructure. In particular, the aspects of *security, resource description, discovery, brokering and negotiation,* are all missing, whilst the general problem of how to compose web services into new ones has hardly be approached (see for example Florescu et al 2002).

3 Semantic Web

The Semantic Web on the other hand has had a lot of publicity, but less enthusiastic commercial support. It has been driven by a more academic approach, and has yet to prove itself within widespread application. Nevertheless, it has an ambitious long-term aim; nothing less than imbuing the Web itself with meaning. That is, providing meaning to the network of *resources* available on the web and, perhaps more importantly, meaning to the *links* that connect them (Koivunen & Miller 2001). Once the web has a mechanism for defining semantics for resources and links, then the possibility for *automatic processing* of the Web by software agents, rather than the constant mediation by people providing meaning to the Web.

This ambitious aim has been there from the beginning (Berners-Lee 1989) as Tim Berners-Lee's original description of the WWW included types for objects and links. However, it was not until the Semantic Web Roadmap (Berners-Lee 1998) that the initiative became fully underway.

The Semantic Web has been developing a layered architecture:

- **Resource Description Framework:** A basic knowledge representation language, describing a graph model and XML format for describing relationships between resources (Lassila & Swick 1999).
- **RDF Schema Language (RDF Schema):** a basic type modelling language for describing classes of resources and properties between them in the basic RDF model (Brickley & Guha 2002).
- **Ontologies:** a richer type modelling language for providing more complex constraints on the types of resources and their properties. The current most complete work is DAML+OIL (Connolly et.al. 2001).
- **Logic and Reasoning:** an (automatic) reasoning system provided on top of the ontology structure to *make new inferences.* Thus using such a system, a software agent can make deductions as to whether a particular resource satisfies it requirements (and vice versa) (e.g. RQL (Karvounarakis et. al. 2002).

Thus the Semantic Web initiative has an ambitious programme to bring existing work on knowledge representation and reasoning to bear on the largest information resource of all. Nevertheless, the work on all areas has been slow, with the process returning to its beginnings on several occasions. This has given the impression that the activity is of largely academic interest, whilst of course the application and potential of this work is enormous.

Applications of RDF have emerged however, notably, Dublin Core (Miller et al 1999), RDF Site Summary (Beged-Dov et. al. 2000), Composite Capability/Preferences Profiles (Klyne et. al. 2001), and most recently proposals for the Protocol for Internet Content Selection (Brickley & R.Swick 2000) and Protocol for Privacy Preferences Project (McBride et. al. 2002). These are all applications that are ideal for the Semantic Web as they describe properties of web based resources. Nevertheless, each individually could be described using some domain specific method, and possibly in a more succinct manner. What has yet to be demonstrated is the benefits to be gained from expressing such applications within a single framework, one that allows semantics based interoperability. Web Services provides an ideal environment where the advantages of a joined up semantic approach could be demonstrated.

4 Integration via Meaning

In a briefing that has subsequently become well-known Keith Jeffery proposed a three layer architecture for considering a future distributed information systems architecture (Jeffery 2000). These three general levels were:

- **Computation/Data layer**: the basic protocols for accessing, invoking and scheduling the use of computation and data resources. This includes the fundamental networking protocols, the addressing of resources, and the low-level data formats and remote method invocation to access the raw power. However, to use this layer effectively, the user has to know in advance the location, the data formats and the functionality of resources available.
- **Information Layer**: information on resources available on the distributed system is available via *descriptions of those resources* (commonly known as *Metadata*). This will allow the discovery and negotiation of resources within known domains of practice: that is the *meaning* of the metadata is agreed within a particular community.
- **Knowledge Layer:** access to resources is negotiated through the semantics of metadata encapsulated within the system. This layer will provide *contextualised* access to information, utilising semantic knowledge and reasoning. Processes within this layer include reclassifying information against new ontologies, to enable interoperability between different semantics, and knowledge discovery in databases (including data mining).

Whilst originally promoted within the domain of distributed Grid systems supporting an infrastructure for scientific applications, this analysis of distributed systems applies equally well to the Web. Indeed, the distinction is likely to be nonsensical as the whole world converges on a single architecture for wide-area distributed systems.

Within the Web, the basic existing infrastructure (for addressing Data) augmented with the basic Web Services architecture (for accessing computational resources) forms the *data and computation* layer, with the familiar tool of the Web Server as the defining tool; one which dumbly responds to requests for resources, possibly passing control to other systems in a peer-to-peer manner.

Existing community efforts to standardise on particular XML Schemas for both data and Web Services, particularly some infrastructure efforts including those mentioned above (P3P, PICS, CC/PP, RSS) - which can be seen as augmenting the basic Web Service architecture, distinguish the *information layer of* the Web. In this layer the concept of the *Portal* is the defining tool. This a tool that uses metadata defined within a known domain to access resources which, although they are unknown to the user, have a previously agreed semantics and can be used by the user. Thus the intelligence still resides with the human user.

The Knowledge layer within the Web will be supported by the Semantic Web. We shall discuss in more detail what this entails.

Jeffery identifies *control* as a connecting feature between the layers: knowledge about the relationships between resources controls access to information about resource, which in turn controls access to the resources themselves. We could equally well say that another distinguishing feature of the layers is the *decrease* in the necessity for *prior knowledge* as we go up the layers, and the increase in *delegation,* as more functions are delegated from the user to the system, ultimately to a system of intelligent agents. Thus in the data/computation layer, users exercise direct control upon resources which they know about in advance. In the information layer, users delegate some tasks, such as resource discovery and access, to portals, and may not have knowledge of the location of resources, but they have to have prior knowledge of the portal and the nature of the information that that portal processes.

In the Knowledge layer, delegation should increase, prior knowledge decrease, so the user will be able to delegate the task of discovering appropriate information sources, and also not need to know the meaning or existence of that information in advance. The user should be able to specify the task that he or she desires to perform and then delegate it to the system. Thus, the defining software component for the knowledge layer is the *Intelligent Agent.*

Three types of agent will typically be present within this system:

- **User Proxy agent:** An agent acting on the users behalf. It will initiates and coordinates user actions and queries to the web, seek out and offer to the user relevant resources, acts as user proxy to react when user is absent, and automatically responds to requests on the user according to user preferences and security settings.
- **Resource agent:** An agent acting on the behalf of a resource. It will respond to requests for access to resources, coordinate queries with other resources, and control and monitor access to the resource.
- **Broker agent:** These agents are not connected to any resource, but provide a discovery and negotiation service for other agents, searching for appropriate resources, negotiating access and monitoring usage.

Agents will thus negotiate with each other on a basis of attempting to determine the meaning of resources - thus the main integration mechanism of a Semantic Web enabled Web Service architecture will be meaning itself. We will have *Integration via Meaning.* Meanwhile, the portals and other tools which are at the lower levels will *disappear into the infrastructure of the Web itself;* the user will need no prior knowledge of the portals or the semantics they support; the interaction with the portal will be mediated by the user's agent which will attempt to resolve the semantics provided by the portal with the semantics of the user.

5 Particular functions of the Semantic Web

Particular functions will be provided via this Semantic Web layer on top of Web Services, as processed via the actor's agents.

- **Resource organisation, searching and discovery.** By expressing the semantics of resources in terms of Ontologies, together with interoperability and reasoning, agents can discover relevant resources, and present them back to the user in the user's own terms. This would include access to web service descriptions; currently these are expressed in terms of either interface descriptions, or domain specific criteria. In the Semantic Web, web service descriptions would include a formal expression of the functionality of the service; a proof could determine whether the service satisfies the user's requirements.
- **Brokering and negotiation.** Once suitable resources have been identifies, intermediary brokers can reconcile the requirements of users and resources, in terms of their meanings, to determine whether a suitable deal or contract can be established for usage of the resource.
- **Trust management.** Establishing trust between agents that have no prior knowledge of each other is a major problem within the Web, and one which could potentially prevent the establishment of a universal Web Service infrastructure. Agents need to be able to negotiate access to resources, through a process of negotiation. Again Semantic Web techniques can enable this. Services could publish policies, user agent could present their credentials, possibly with reference to a trusted third party, and once trust has been established, negotiate suitable access rights and obligations (Dimitrakos 2002).
- **Quality of service.** Similarly, users and resources may have conditions with respect to the quality of service they require (e.g. in terms of response time, accuracy of data, level of confidentiality). These properties of resources can be expressed in Semantic Web terms and negotiated via agents.
- **Auditing and monitoring.** Monitoring agents can track the usage of the web, and provide audit trails. Included in this mechanism would be functionality to track expenditure and perform billing.

- **Personalisation.** User agent will be able to represent and enforce the preferences of the user. This would include how the user would prefer their own information to be used, and also what requirements they might have on the information they would like to access and how it is presented back to them. This infrastructure is already emerging with CC/PP, P3P, and PICS. Through negotiation with RSS, and other specifications such as XHTML modules, a negotiation of the form of information that a user requires can be performed.

6 Research programme at BITD CLRC

The Business and Information Technology Department of CLRC has a research and development programme focused on realising the various components of the emerging Web combining Web Services with the Semantic Web. A collection of new projects has recently started which are developing fundamental components of this architecture, and also applying the architecture in practice. We consider some of these projects.

- **Data and Information Portals: Universal access to information.** These two projects, one within the e-Science programme (Ashby et. al. 2001a, 2001b) developing a portal for accessing scientific data across a wide variety of domains, and the Information portal, providing single point of access to business information provide fundamental components of the Information Web which can be used to build the semantic layers above.
- **SWAD-Europe: bringing the Semantic Web to reality.** The SWAD-Europe project intends to deepen the experience with the current generation of Semantic Web technologies, providing tools, demonstrators and applications to show the practicality of using the semantic web to deliver added value now. Of particular interest is the application to trust management, developing mechanisms to negotiate access to resources through presenting credentials to policies and using a process of negotiation; and the use of controlled vocabularies as restricted ontologies to provide focussed access to information (SWAD-Europe; Brickley et. al. 2002). Thus these applications will provide evidence that the Semantic Web can augment a Web Service architecture.
- **GRASP: Bringing the Grid to business.** The GRASP project aims to explore a new advanced system infrastructure for Application Service Provision based on GRID technologies. An ASP, realized using Grid technologies, will be characterized by a high level of scalability and reliability, innovative solutions for the security, for the accounting, the Quality of Service (QoS) and for resource management (GRASP). Thus GRASP will develop semantic techniques to augment global computing infrastructure (as realised in the Grid) and demonstrate its application within business applications.
- **PELLUCID: using Agents to coordinate knowledge.** The objective of the Pellucid project is to develop an adaptable platform for assisting organisationally mobile employees by providing a suitable knowledge of the task in hand to the employee. It is taking the approach of *agent supported knowledge management.* Thus intelligent agents, both user proxies and task agents, acting in consort with a workflow system will use domain knowledge to reason what information is relevant to a particular employee at any instant. (PELLUCID). Thus within this project, we are developing intelligent agent systems negotiating with user profiles to provide domain specific information through reasoning on the current context of that user - important features of the merger of the Semantic Web and Web Services.
- **I-Trust: establishing trust between agents.** This working group is looking at trust management at a high level to establishing security and confidence in the global computing infrastructure (I-TRUST)
- **E-Lege: introducing the Grid into e-Learning.** This working group is considering how to introduce the global computing infrastructure into the field of e-Learning.

7 Conclusions

With the advent of Web Services, and the long development of the Semantic Web coming to maturity, it is inevitable that they should be considered as complementary. Indeed, others have discussed similar ideas (e.g. De Roure 2001; Houstis et. al. 2002; Ryssevik 1999). In this paper, however, I have set the combination within the context of a structure of the three layered architecture and a notion of *decreasing prior knowledge,* and *increasing delegation.* Together they offer the opportunity for a new global computing infrastructure, and I consider some specific areas where significant gains could be found through this combination.

Ultimately, will the combination of Semantic Web and Web Services take off and become commonplace in the development of information systems? This is hard to say - there have been many attempts at providing „universal computing solutions“, which have had only limited success. Perhaps we can say that this one has a better chance than many because of the momentum behind it, and the existing much higher level of basic infrastructure (in networks, protocols and software platforms) than there has ever been before.

However, there is still a need for a „killer app“ to get this emerging architecture onto everybodies computer and mobile phone, in the way the current web is now. To determine what that might look like, we should consider what has made the WWW so successful - it was not the most advanced information system available at the time. However, the key features were all things which made it accessible to people: it was easy to set up, both as user and, crucially, as content provider; it provided an immediate feedback so the user could how they gained by using it (especially when made more visually appealing through the inclusion of images in Mosaic); and it is was very tolerant to all to human errors, not collapsing when faced with poorly produced pages, or pages which were not there at all! With the Web Service infrastructure offering the potential for ever more increasingly complex applications, and more and more of the functions of the system becoming opaque to the user, the intelligent use of the Semantic Web offers the opportunity to recover accessibility for humans.

8 References

J V Ashby, J C Bicarregui, DR S Boyd, K Kleese van Dam, S C Lambert, B M Matthews, K D O'Neill. (2001a): The CLRC Data Portal *British National Conference on Databases*

J V Ashby, J C Bicarregui, D R S Boyd, K Kleese van Dam, S C Lambert, B M Matthews, K D O'Neill (2001b): A Multidisciplinary Scientific Data Portal *HPCN 2001: International Conference on High Performance and Networking Europe* Amsterdam

G. Beged-Dov et. al. (2000): RDF Site Summary (RSS) 1.0 http://purl.org/rss/1.0/spec

T. Berners-Lee (1989): Information Management: A Proposal, *CERN* http://www.w3.org/History/1989/proposal.html

T. Berners-Lee (1998): Semantic Web Road Map http://www.w3.org/DesignIssues/Semantic.html

D. Brickley and R.V. Guha.(2002): PICS Ratings Vocabularies in XML/RDF *W3C Note* http://www.w3.org/TR/rdf-pics

D. Brickley and R.Swick.(2000): RDF Vocabulary Description Language 1.0: RDF Schema *W3C Working Draft* http://www.w3.org/TR/rdf-schema/

D. Brickley, S Buswell, B Matthews, L Miller, D Reynolds, M Wilson (2002):SWAD-Europe: Semantic Web Advanced Development in Europe *Presented at the International Semantic Web Conference.*

D. De Roure, N Jennings, N Shadbolt (2001): Research Agenda for the Semantic Grid: A Furture e-Science Infrastructure http://www.semanticgrid.org/html/semgrid.html

CERIF: the Common European Research Information Format www.cordis.lu/cerif/

CLRC Data Portal Project www.escience.clrc.ac.uk/Activity/ACTIVITY=DataPortal

D. Connolly, F. van Harmelen, I. Horrocks, Deborah L. McGuinness P. F. Patel-Schneider, L. A Stein (2001): DAML+OIL Reference Description W3C Note 18 December 2001

T. Dimitrakos, I. Djordjevic, B. Matthews, J. Bicarregui, C. Phillips (2002): Policy-Driven Access Control over a Distributed Firewall Architecture Policy 2002: IEEE 3rd International Workshop on Policies for Distributed Systems and Networks IEEE-CS, California, U.S.A.,

Dublin Core Metadata Initiative
www.dublincore.org/

EbXML: (Electronic Business using eXtensible Markup Language) *Home page*
http://www.ebxml.org

E-LEGE: E-Learning within a Grid environment
http://www.bitd.clrc.ac.uk/Activity/lege-wg/

eGIF (2002) e-Government Interoperability Framework Part Two: Technical Policies and Specifications *Version 4, Office of the e-Envoy,*
http://www.govtalk.gov.uk/documents/e-GIF4Pt2_2002-04-25.doc

D. Florescu, A. Grünhagen, D. Kossmann (2002): XL: An XML Programming Language for Web Service Specification and Composition *WWW2002,*
http://www2002.org/CDROM/refereed/481/index.html

I. Foster , C. Kesselman (eds.) (1999): The GRID: Blueprint for a New Computing Infrastructure, *Morgan-Kaufmann.*

A. Gokhale, B Kumar, A Sahuguet (2002): Reinventing the Wheel? CORBA vs. Web Services. *WWW2002, Web Services and Metadata track,*
http://www2002.org/CDROM/alternate/395/index.html

GRASP: Grid architecture for Application Service Provision
http://www.bitd.clrc.ac.uk/Activity/GRASP

C. Houstis, S. Lalis, V.Christophides, D. Plexousakis, M. Vavalis, M. Pitikakis, K. Kritikos, A. Smardas, X. Gikas, (2002): A Service infrastructure for e-Science: the case of the ARION system, *submitted to the E-Services and the Semantic Web workshop (ESSW2002).*
http://dlforum.external.forth.gr:8080/papers/ARION-paper_v52.pdf

IBM Web Services Home Page. http://www-3.ibm.com/software/solutions/webservices/

R. Irani (2001): ebXML and Web Services: The Way to Do Business
http://www.webservicesarchitect.com/content/articles/irani03.asp

I-TRUST: Trust Management in Dynamic Open Systems http://www.bitd.clrc.ac.uk/Activity/itrust/

K G Jeffery (2000): Knowledge, Information and Data. *A briefing for OST*
http://www.bitd.clrc.ac.uk/Publications/1272/KnowledgeInformationData20000124.htm

G. Karvounarakis, S Alexaki, V Christophides, D Plexousaki M Scholl (2002) RQL: A Declarative Query Language for RDF. *WWW2002*
http://www2002.org/CDROM/refereed/329/index.html

G. Klyne, F. Reynolds, C. Woodrow, H. Ohto,(2001): Composite Capability/Preference Profiles (CC/PP): Structure and Vocabularies *W3C Working Draft 15 March 2001*
http://www.w3.org/TR/2001/WD-CCPP-struct-vocab-20010315/

M-R Koivunen, E. Miller (2001): W3C Semantic Web Activity, Proceedings of the Semantic Web Kick-off Seminar in Finland,
http://www.w3.org/2001/12/semweb-fin/w3csw

O. Lassila R. Swick (1999): Resource Description Framework (RDF) Model and Syntax Specification *W3C Recommendation 22 February 1999*
http://www.w3.org/TR/1999/REC-rdf-syntax-19990222

B. McBride, R. Wenning, L. Cranor, (2002): An RDF Schema for P3P *W3C Note 25 January 2002*
http://www.w3.org/TR/2002/NOTE-p3p-rdfschema-20020125

E. Miller, P Miller, D Brickley (1999): Guidance on expressing the Dublin Core within the Resource Description Framework (RDF) *Dublin Core Metadata Initiative Draft Proposal*
http://www.ukoln.ac.uk/metadata/resources/dc/datamodel/WD-dc-rdf/

.NET Microsoft .NET Homepage
http://www.microsoft.com/net/

PELLUCID: An Agent Based Platform for Organisationally Mobile Public Employees
http://www.bitd.clrc.ac.uk/Activity/PELLUCID
http://www2002.org/CDROM/refereed/329/ - note1

J. Ryssevik, S. Musgrave (1999): The Social Science Dream Machine: Resource discovery, analysis and delivery on the Web, *the IASSIST Conference, Toronto,* www.nesstar.org/papers/iassist_0599.html

SOAP Version 1.2 Part 1: Messaging Framework *W3C Working Draft 17 December 2001* http://www.w3.org/TR/2001/WD-soap12-part1/

SOAP Version 1.2 Part 2: Adjuncts *W3C Working Draft 17 December 2001* http://www.w3.org/TR/2001/WD-soap12-part2

Sun Microsystems (2001): Web Services Made Easier: the Java APIs and Architectures for XML *Sun Microsystems white paper* http://java.sun.com/xml/webservices.pdf

SWAD-Europe: Semantic Web Advanced Development for Europe http://www.bitd.clrc.ac.uk/Activity/SWAD-Europe

UDDI: Universal Discovery Description and Integration, *Home Page* http://www.uddi.org

W3C: World-Wide Web Consortium www.w3.org

WSDL: (2001) Web Services Description Language (WSDL) 1.1, *W3C Note* http://www.w3.org/TR/wsdl

X Protocol: XML Protocol Working Group Home Page http://www.w3.org/2000/xp/Group/

9 Acknowledgements and Contact Information

I would like to thank my colleagues in CLRC Business and Information Technology Department for their help and advice over many discussions on this topic.

Brian Matthews
CLRC
Rutherford Appleton Laboratory
Didcot
OX11 0QX
UK

e-mail: b.m.matthews@rl.ac.uk